Geriatric Veterinary Care for Fish Patients

E. Scott Weber III, VMD, MSc Aquatic Vet Sci/Pathobiology

KEYWORDS

- Fish longevity • Environmental quality • Infectious disease
- Fish reproduction

There is little evidence-based research and scientific literature available for providing geriatric care for fish patients. Fish can have tremendous longevity. Although the average life span for most fish species can be only a few days to weeks for the beginning hobbyist, it is becoming more common for clients to have animals for several decades with the advent and continued development of improved life-support systems, husbandry, water quality additives, and fish nutrition. This article discusses fish longevity for several popular species, addresses environmental quality issues for geriatric patients, and provides information on the most common challenges, from a veterinary perspective, to maintain fish over the years.

FISH LONGEVITY AND SENESCENCE

Several commonly kept species of fish have life spans that rival and greatly exceed many other vertebrates kept as domestic pets. As recently as the 1970s, a few academicians theorized that fish were unique in that they do not age, but others have published literature reviews and research from senescence studies in guppies refuting this hypothesis.[1] Some researchers have shown longevity increases with genome size in Acipenseriformes, Cypriniformes, and Salmoniformes.[2] Because fish are highly represented with a large number of species known to live for more than 100 years, work by Reznick and colleagues[3] suggests that, unlike birds and mammals, fish have evolved delayed senescence based on increased fecundity with age, that slower growth delays maturity, and that lower mortality rates lead to maximum life spans similar to birds and mammals. Guppies have been used as a model for understanding evolutionary theory and natural senescence, linking age-specific changes in reproduction with mortality rates, and showing that reproductively active animals may age more quickly.[4,5] Other factors may also play a part in aging of captive and wild fish species including water temperature, marine verses freshwater environs, and deep dwelling

Aquatic Animal Health, VM: Medicine and Epidemiology, University of California, Davis, 2108 Tupper Hall, Davis, CA 95616, USA
E-mail address: epweber@ucdavis.edu

verses pelagic or near-shore animals.[6] The mechanisms for increased longevity of some species of deep-dwelling scorpaenid fishes include reduced oxidative stress as compared with near-shore fish species.[6]

When a client decides to invest in a freshwater aquarium, pond, or marine system they should be advised that many commonly sold fish species easily live for 5 to 40 years or more in captivity. This fact will greatly influence many factors, such as enclosure size, pond/tank placement, or the type of aquarium animals purchased. Many fish offered for retail are sold as juveniles and the aquarist needs to be able to provide long-term care for these animals. Some important considerations are the adult size of animals; potential coloration changes for certain species, such as marine angelfish when they mature; changes in dietary requirements; behavior changes; or evolving habitat requirements.

In the United States, backyard koi (*Cyprinus carpio*) ponds have experienced exponential growth over the last decade. There are many sources for obtaining koi from inexpensively bred animals, ranging from only $2 to $3, to show-quality imported animals from Japan costing more than $100,000. In Japan, certain koi have been handed down from generation to generation with anecdotal stories of animals ranging in age from 120 to 200 years old. In the United States, many owners have collections that contain 20- to 30-year-old animals.

For tropical, freshwater, and marine aquaria, a variety of species are available to create fish communities. Some of the most common species available for community freshwater aquaria, such as many livebearers, *Danio* sp, and *Characin* sp, typically considered annual fish in the wild, can live for 2 to 6 years in captivity. Larger species of marine and freshwater fish can live for 10 to more than 30 years. Marine tropical fish commonly sold as schooling animals for marine aquaria can live more than 10 years, a damsel (*Stegastes altus)* was recorded to have lived for 15 years[7] and some of the labrid reef fish have recorded life spans of 1.5 to 11 years in the wild.[8]

Marine reef tanks can literally last for generations if cared for properly. Many corals and other invertebrates, such as anemones, can live for decades. In public aquaria, it is generally recognized that it can take anywhere from 3 to 10 years for a newly established live reef tank to start meeting exhibit design expectations. Many species of corals in public aquarium collections are extremely valuable from economic and conservation perspectives, as some older collections have invertebrate species that are endangered or extinct in the wild.

Public aquaria offer creative habitat designs, specialized life support, and trained husbandry expertise that enables them to exhibit some of the oldest specimens known in captivity for many fish species. (**Fig. 1**) The elasmobranchs (sharks, skates, and rays) are important collection animals in many institutions for a variety of display and interactive exhibits. These animals typically mature slowly and have great longevity in the wild and in captivity. In addition, there are many species with unique husbandry requirements, such as certain rockfish (*Sebastes* sp) and sturgeon (*Acipenser* sp), exhibited in these institutions that can live for more than 100 years. Many public aquaria, through optimizing husbandry and habitat design, allow many species to mature more naturally because of improved water quality and greater water volume. These conditions make it possible for some species of freshwater fish, such as silver arrowana (*Osteoglossum bicirrhosum)* and arapima (*Arapima gigas)*, and of marine animals, such as goliath grouper (*Epinephelus itajara*) and orbicular batfish (*Platax orbicularis*), to grow to their appropriate mature sizes in captivity. Some longevity records for several commonly kept fish species are found in **Table 1**.

Fig. 1. This is a community marine aquarium depicting the warm-water Atlantic community at the New England Aquarium in Boston.

ENVIRONMENTAL QUALITY

To optimize husbandry for aquatic animals, one must manage environmental quality conditions. Environmental quality for aquatic ecosystems includes water, air, sound, and light parameters. To provide a healthy habitat, aquarists study animals' natural history requirements, reproducing an appropriate environment for the captive species or collection. Disease may occur when any of these environmental parameters deviates from normal, either acutely as in the case of chlorine or ammonia toxicity, or chronically as in the case of nitrate or heavy-metal toxicity.

Evaluating environmental quality will be different for clinic visits compared with field consultation. Some tests are regularly performed on stable parameters, such as ammonia, pH, salinity, nitrite, and nitrates in the laboratory; whereas accurate testing must be completed onsite for dissolved oxygen, temperature, and turbidity. When analyzing the aquatic environment, data can be classified into three main categories: (1) physical parameters, (2) water chemistry and (3) water biology. Some common water chemistry parameters analyzed regularly include dissolved oxygen, salinity, pH, alkalinity, hardness, ammonia, nitrites, nitrates, and phosphates.

Understanding the nitrogen cycle is critical to successful fish husbandry. This cycle refers to the conversion of ammonia to nitrate. Ammonia is produced by uneaten food, animal waste, and decaying organics with influences from temperature and pH that affect toxicity. In aerobic conditions ammonia is converted to nitrite by way of the bacteria nitrosomonas, and then converted to nitrates by way of microbes called nitrobacters. Acute toxicity and death can occur with high ammonia and nitrite levels measured in parts per million (ppm). High ammonia and nitrite toxicity with acute mortalities are often attributed to newly established aquaria or ponds that have had large stocking densities before proper establishment of appropriate microbial populations in the bio-media or filter.[21] Nitrates cause more chronic problems. Because nitrates are the end product of bio-nitrification, nitrates accumulate in aquaria and ponds over time. Management of nitrates requires regular maintenance and water-quality testing. Recent research also indicates that nitrate levels previously thought to be safe are actually the cause of several chronic health conditions in a variety of species of fish and invertebrates.[22] Chronic and acute toxicity caused by high nitrates

Table 1
Commonly kept fish species and record life spans

Order/Family	Genus/Species	Common Name	Wild (Y)	Captivity	References
Poeciliidae	*Gambusia affinis*	Mosquito fish, gambusia	1.5	—	Altman & Dittmer[9]; Krumholtz[10]
Cyprinidae	*Barbus bynni bynni*	Niger barb (+)	—	16.3	Altman & Dittmer[9]; Flower[11]
	Carassius auratus	Goldfish	41.0	30.0	Flower[11]; Carlander[12]; Moyle[13]; Bobick & Peffer[14]
	Cyprinius carpio	Carp	38.0	47.0	Flower[15]; Hinton[16]
	Cyprinus carassius auratus	Goldfish/carp hybrid	—	10.0	Flower[11]
	Leuciscus orfus	Golden orfe (+)	—	14.25	Flower[11]
Syngnathidae	*Hippocampus hippocampus*	Short-snouted sea horse	—	1.3	Altman & Dittmer[9]; Flower[11]
	Hippocampus erectus	Atlantic-lined sea horse or Northern sea horse	1.0	—	Herald & Rakowicz[17]; Strawn[18]
Mormyridae	*Gnathonemus cyprinoides*	Trunkfish	—	7.1	Flower[11]
	Pollimyrus isidori isidori	Mormyrid (+)	29	28.0	Altman & Dittmer[9]; Flower[15]; Hinton[16]
	Mormyrus kannume	Elephant-snout fish (+)	—	6.3	Flower[11]
Notopteridae	*Xenomystus nigri*	African brown knifefish	—	11.4	Altman & Dittmer[9]; Flower[11]
Osteoglossidae	*Osteoglossum bicirrhosum*	South American silver arowana	6.5	—	Hinton[16]
Anabantidae	*Ctenopoma kingsleyae*	Tail-spot climbing perch	—	8.7	Altman & Dittmer[9]; Flower[11]
	Anabas testudineus	Climbing perch	—	11.0	Altman & Dittmer[9]; Flower[15]
	Macropodus opercularis	Paradise fish	—	8.0	Altman & Dittmer[9]; Flower[11]
Chaetodontidae	*Chaetodon lineolatus*	Lined butterflyfish	10.0	—	Hinton[16]
	Chaetodon lunula	Raccoon butterflyfish	9.0	—	Hinton[16]
	Chelmon rostratus	Copperband butterflyfish	10.0	—	Hinton[16]
	Forcipiger flavissimus	Long-nosed butterflyfish	18.0	—	Hinton[16]
Cichlidae	*Acara tetramerus*	Two-spot acara, saddle cichlid	—	7.0	Altman & Dittmer[9]; Flower[11]
	Cichlasoma cyanoguttatum	Rio Grande perch, Texas cichlid	—	5.0	Altman & Dittmer[9]; Flower[15]
	Tilapia spp	African cichlid	—	7.0	Altman & Dittmer[9]; Flower[11]
Labridae	*Coris julis*	Mediterranean rainbow wrasse	7.0	—	Hinton[16]

Pomacanthidae	*Centropyge flavissimus*	Lemonpeel angelfish	11.0	—	Hinton[16]
	Euxiphipops navarchus	Blue-girdled angelfish	15.0	—	Hinton[16]
	Pomacanthus imperator	Emperor angelfish	14.0	—	Hinton[16]
	Pygoplites diacanthus	Regal angelfish	14.5	—	Hinton[16]
	Amphiprion clarkia	Clarkii clownfish, Clark's anemonefish	11.0	—	Moyer[19]
	Amphiprion ephippium	Fire clownfish	16.0	—	Hinton[16]
	Dascyllus aruanus	Three-stripe damsel, Humbug dascyllus, Banded dascyllus	6.0	—	Hinton[16]
	Centropyge tibicen	Keyhole angelfish	6.0	—	Moyer[19]
Polypteridae	*Polypterus senegalus*	Cuvier's bichir	—	34.0	Altman & Dittmer[9]; Flower[15]
Clariidae	*Clarias lazera*	African walking catfish (+)	—	16.2	Altman & Dittmer[9]; Flower[11]
Ictaluridae	*Ictalurus lacustris punctatus*	Albino channel catfish	13.0	—	Altman & Dittmer[9]; Lewis[20]
Loricariidae	*Hypostomus punctatus*	Common plecostomus	18.0	—	Hinton[16]
Mochokidae	*Synodontis schall*	Upside-down catfish	12.0	31.0	Flower[11]; Hinton[16]
Pimelodidae	*Pimelodus* spp	Pim catfish	—	7.0	Altman & Dittmer[9]; Flower[11]
Tetraodontidae	*Canthigaster solandri*	Common sharpnose puffer	7.0	—	Altman & Dittmer[9]; Flower[15]

+ indicates that individual was still alive at the time that life span was recorded.

Data from Carey JR, Judge DS. Longevity records: life spans of mammals, birds, amphibians, reptiles, and fish. Monographs on population aging, 8. Rostock (Germany): Odense University Press, Max-Planck-Geselschaft; 2002. Available at: http://www.demogr.mpg.de/?http://www.demogr.mpg.de/longevityrecords/.

affect larger fish, such as Siberian sturgeon (*Acipenser baeri*), greater than smaller animals, so as animals mature there may be a greater need to more aggressively manage water quality for captive or aquaculture kept broodstock.[23] The author recommends remediation for nitrate levels that are above 10 ppm, resulting in gravel/sediment washing with weekly water changes and regular backwashing of filters.

Metals may also be present in fresh and marine water sources. Copper is especially common and toxic to fish even at low levels. Other metals that may be present in tap water include lead and iron, especially in older plumbing systems. The long-term consequences of heavy metals in aquariums and ponds is unknown, but in wild populations chronic exposure to heavy-metal levels naturally or through pollutants have been attributed to certain types of cancer and hepatotoxicity.[24–26] Aquariums and ponds should have heavy metals checked annually in systems that use natural feed springs, streams, or wells; whereas hobbyists who use public water systems may be able to view heavy-metal test results performed regularly and reported by their local water authority in their annual report.

Hydrogen sulfide (H_2S) is a water-soluble gas produced by the bacterial decomposition of organic debris under anaerobic conditions. Many factors that contribute to an increased organic load in the pond or aquarium include: fine substrate, clay or substrates, areas of decreased water circulation, algae or plankton die-offs, uneaten feed, dead fish, leaves, grass clippings, manure form livestock, tree stumps, waste from live fish, and overstocking. The most common characteristics of aquatic systems containing H_2S are a rotten-egg smell and black sediment. The toxicity of H_2S is influenced by increased temperature and decreased pH. The effects of H_2S on vertebrates and invertebrates can be lethal and the toxicity of H_2S has been studied for several aquatic species. Hydrogen sulfide often develops in ponds or aquaria that have been established for several years and that have not undergone regular maintenance, including gravel washing or sediment exchange.[27] Fish should be removed without disturbing the sediments in these systems before any aquarium or pond maintenance is conducted that will disturb sediment layers.

Lighting provides behavioral cues to animals, affects endocrine function, and may be an important component of nutrition for a variety of aquatic animals. One area the pet industry is most acutely aware of is lighting requirements for coral reef invertebrates. Inappropriate lighting conditions may be implicated for nutritional deficiencies of vitamin D and reproductive problems in some species of fish. More research on aquatic animals needs to be conducted in this area to understand true lighting requirements and chronic health issues.

NUTRITIONAL CONCERNS

With more than 1000 species available for marine and freshwater hobbyists, there are many fish for which nutritional and dietary requirements are unknown. Maintaining an appropriate diet is critical for fish throughout their life span, and these diets may even need to change as fish mature. The best approach is to provide a balanced diet in the form of pellets, flakes, crumble, or gel and offer a variety of other feedstuffs periodically for variety. There are several chronic problems that develop from inappropriate nutrition. In piscivorous fish that are kept as pets, such as Oscars (*Astronotus ocellatus)*, flowerhorn cichlids (*Cichlasoma* sp), and marine lionfish (*Pterois volitans*), hobbyists often feed these animals live or frozen fish. Certain fish-food items used in aquariums come from the family Clupidae and contain thiaminase, which is exacerbated by freezing and causes thiamine deficiency.[28] This deficiency can manifest as

neurologic, reproductive, and skeletal problems in adult fish.[29–31] Usually these animals are large piscivorous freshwater species that have been fed frozen marine fish, such as herring, mackerel, or certain live feeder fish, as an exclusive diet. **Fig. 2** shows a Nile perch (*Holocentrus ascensionis*) that exhibited neurologic symptoms and on radiography had extensive bony lesions that were associated with thiamine deficiency. Fish usually respond well once their diet is adjusted or supplemented with thiamine, and after thiaminase-containing feed sources are eliminated.

Thyroid hyperplasia or goiter can also occur in captive aquarium fish. Iodine is one example of a natural component of seawater that can be made biologically unavailable in a system disinfected with ozone.[32] Many species of teleosts and elasmobranchs can develop thyroid hyperplasia from a lack of environmental or dietary iodine.[33–35] High levels of nitrate can also act as a goitrogen for a variety of freshwater and marine animals.[35] Some cases, when treated early, have reversed after animals were provided appropriate dietary supplementation or iodine levels were maintained in marine systems.

Hepatic lipidosis/steatitis is a common finding in aquarium species, and is very common in geriatric animals. In other higher vertebrates including humans, hepatic steatitis and lipidosis is considered a silent killer, rather than just being a benign or incidental finding.[36] The etiology of hepatic lipidosis and steatitis is not known for the majority of marine and freshwater tropical fish, although it is loosely and largely associated with poor nutrition and over feeding. In aquaculture-reared animals hepatic lipidosis develops commonly in animals fed polyunsaturated fats.[37] The development of hepatic lipidosis in freshwater fish has been attributed to the fatty-acid metabolism of polyunsaturated fats.[38] Hepatic lipidosis has been observed in common carp (*Cyprinus carpio*) fed alternative soy-based or yellow fats[39]; in aquaculture-reared sea bream (*Sparus aurata*) that were highly stocked and fed fatty-acid deficient diets; and in several marine fish species fed artificial diets.[40] All of these studies suggest fish diets should contain limited levels of polyunsaturated fats, require balanced essential fatty acids, and need more research to be conducted and published for commonly kept pet fish species for short-term and long-term care.

INFECTIOUS DISEASES

Mycobacteriosis is a common disease in wild and captive fishes, and many species of marine and freshwater fish are susceptible to infection. It is a pathogen that is ubiquitous in natural and captive environments. Mycobacteria cause problems in the ornamental-marine and freshwater fish trade worldwide, and infected asymptomatic animals can cause insidious problems with long-term management and control.
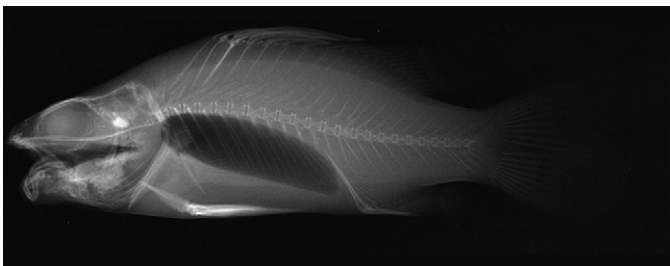

Fig. 2. A radiograph taken in right lateral recumbency of a Nile perch with deviation in dentary and articular bones of the mandible caused by a thiamine deficiency.

This disease was first reported in 1897 by Bataillon in a common carp, and the three most commonly recognized etiologic agents of atypical mycobacteriosis in fish are *Mycobacterium marinum, Mycobacterium fortuitum, and Mycobacterium chelonae* in ornamental fish.[41]

Clinical signs of mycobacteriosis include listlessness, lethargy, and isolation from other fish.[42] Many animals may exhibit emaciation, dermatitis, exophthalmia, ascites, coelomic distension, or ulceration. Fish can exhibit profound emaciation despite a voracious appetite, and some fish have extensive epaxial-muscle wasting making them resemble a tadpole or lollipop. Many animals have skin ulcerations that may or may not have skeletal-muscle involvement, and in a few cases spinal lesions have been documented causing scoliosis and lytic changes in the bone.[42] Fish may be infected, with or without clinical signs, from weeks to years. Gross necropsy lesions caused by mycobacteriosis include gray/white to tan miliary granulomas found in virtually any parenchymatous tissue; the spleen, kidney, and liver are the most common organs affected.[42] Enlarged organs, coelomitis, and coelomic fluid may be apparent. Transmission of this bacterium is primarily through consumption of contaminated feed, cannibalism of infected fish, or aquatic detritus. Environmental conditions including low levels of dissolved oxygen, low pH, high organic loads, and warm water predispose to infectious outbreaks.

There is no ante mortem testing available for diagnosing atypical mycobacteriosis in fish patients. Acid-fast staining of anal swabs can give misleading results and lead to diagnosing false-positive animals in infected systems because of the ubiquitous nature of the pathogen, the possibility of mycobacteria passing through the fish's gastrointestinal tract, and the presence of other acid-fast staining bacteria.[43] A negative result may simply suggest an animal is not shedding mycobacteria at the time of testing. Histopathology with Fite's acid-fast stain is the current method of choice when coupled with molecular diagnostics and clinical symptoms. Polymerase chain reaction of infected tissues as a confirmatory test is sensitive and accurate and offers rapid results, but is also expensive. Culture of affected tissues coupled with molecular testing and histopathology is the gold standard, but it can take several months to finalize results, which makes this impractical in more acute outbreaks.

There is currently no effective treatment for mycobacteriosis, although several experimental regimens have been tried.[44] Treatment suggestions that are reported have not all been supported with histopathology to determine if infections were truly cleared, and many treatment recommendations fell far short of time intervals required to treat other atypical mycobacterial pathogens in terrestrial animals.[45] Another caveat with treatment is the antibiotic treatment regimens and treatment duration for mycobacteriosis in an aquarium or pond, lends to potential antibiotic misuse and bacterial resistance. Management is the only method for controlling this disease until sensitive, specific, expedient, and affordable antemortem testing and treatments become available. Management varies from conservative approaches of zero tolerance for suspected cases with euthanasia and disinfection of systems, to ignoring the pathogen entirely with no action for clinically suspect animals.

Atypical mycobacteriosis can cause infections in humans and other mammals. Tuberculoid infections in humans using public swimming pools were first reported in 1939 in Sweden and cases in the United States emerged in 1951. The causative organism, *Mycobacterium marinum,* was identified in 1954 and is referred to today as ''fish tank granuloma.''[46] All fish should be handled as if they may contain mycobacteria and people who have cuts on their hands or those who are immunocompromised for any reason are at greatest risk.

REPRODUCTIVE PROBLEMS

Many species of fish do not readily breed in captivity. Because of environmental threats and decreasing habitat, breeding fish in captivity may become necessary for the survival of several species in the wild. Fish reproductive problems and anomalies are a common occurrence in public and home aquaria. In the past, many of these cases were diagnosed on necropsy. With advances in fish medicine, reproductive problems are being diagnosed antemortem to allow for treatments. Diagnosis of reproductive related disease begins with a thorough history and water quality evaluation, and knowledge of the individual species' reproductive physiology. Some diagnostic modalities that can be used to evaluate the fish patient are complete blood counts, blood chemistries, ultrasound, radiology with/without contrast, computer assisted tomography, general palpation, laparoscopy, cystocentesis, and cloacal endoscopy.[47] The most common problems encountered clinically include dystocia or egg binding, cystic ovaries, infectious disease, organ prolapse, organ trauma, secondary bacterial infections, and neoplasia. Specific treatments for reproductive problems in fish can include hormonal treatment, surgery, antibiotic or antifungal therapy, environmental changes, and improved nutrition.

NEOPLASIA

Fish are regularly used in environmental and chemical testing to detect and study effects of mutagenic pollutants or compounds.[48] Similar to other vertebrates, several different tumors have been isolated and identified in fish. Many of these tumors have been recorded and archived at the George Washington University Medical Center Registry of Tumors in Lower Animals. Although the significance of tumorigenesis in fish has been primarily of a scientific nature, in the last decade veterinarians have begun diagnosing and treating cancers in a variety of teleosts. Several diagnostic and treatment options have been used for treatment of fish. Weisse and colleagues[49] described the successful removal of a seminoma in a black sea bass (*Centropristis striata*), diagnosing the animal using contrast radiography, contrast spiral CT, and ultrasonography. Harms and colleagues used microsurgery for the removal of an abdominal mass in a gourami, and Lewbart and colleagues also performed surgery to treat an undifferentiated abdominal sarcoma in a koi (*C carpio*).[50,51] Neoplastic lesions can occur anywhere, and in goldfish (*Carassius auratas*) a dermal fibrosarcoma has been reported.[52] Other unpublished cases include diagnosis of intracoelomic lipomas using advanced imaging in goldfish (*C auratas*); koi (*C carpio*); catfish (*Synodontis* sp); and largemouth bass (*Micropterus salmoides*) by the author and Dr Tobias Schwartz at the University of Edinburgh; cryosurgical intervention for squamous cell carcinoma in a kannume (*Mormyrus kannume*) over 6 months managed by Drs Lance Adams, Leslie Boerner, and the author at the New England Aquarium; lymphosarcoma diagnosed in brook trout (*Salvelinus fontinalis*) by the author and Dr Charles Innis at the New England Aquarium; and radiation, surgical, and cryosurgical intervention for a neurofibroma of a goldfish (*C auratas*) performed at Tufts under direction of Dr Joerg Mayer. Diagnostics for neoplasia cases include survey radiography, ultrasonography, positive-contrast radiography, hematology, blood-chemistry analysis, histopathology, and CT. One of the greatest challenges for aquatic animal veterinarians is getting an early and quick diagnosis. In the absence of other clinical abnormalities or behavioral changes, abdominal masses are difficult to detect until abdominal distension is observed. Often, when abdominal distension is first observed, tumors have grown substantially in size and may account for up to 25% or more of the animal's body weight. Other types of cancer, such as

lymphosarcoma, may only be detected toward the end stage of metastatic disease. As more diagnostic modalities are used, modified, or adapted for aquatic animal medicine, earlier detection and diagnoses of cancers can be made for fish patients. Quicker diagnoses afford greater availability and success of other oncologic treatment options, such as chemotherapeutics, surgery, interventional radiology, and radiation therapy. Although surgical procedures are performed more commonly on fish in research, several reports of clinical surgical cases have been described in the literature.[53] Aggressive treatment options are possible in fish and advances in oncology can successfully be applied in aquatic animal medicine. Earlier detection and increased case reporting will enhance the future success rate for cancer treatment in teleosts.

URINARY CALCULI

Many commonly kept marine and freshwater tropical species have urinary bladders and the author has diagnosed and performed surgery on several of these animals after diagnosing urinary calculi using survey radiographs. In a review of the literature, no published cases could be found on this topic. There is one televised account of surgery on a bridal burrfish (*Chilomycterus antennatus*) by Dr Howard Krum on the PBS show called Scientific American.[54] In geriatric animals that are failing to thrive, a survey radiograph should be a routine part of the physical examination.

CATARACTS

Cataracts regularly develop in freshwater and marine species. They can be easily diagnosed on physical examination and may occur from a variety of etiologies. Digenean trematodes, *Diplostomum* spp, are most responsible for cataract development in outdoor pond fish.[55] These parasites are common in freshwater and have a complex life cycle using a mollusk host for reproduction, a secondary fish host for development, and a definitive bird host for maturation. Some other causes for cataract formation in fish include environmental problems, such as chronic oxygen or nitrogen super saturation; nutritional deficiencies; inappropriate lighting; trauma; and other water quality conditions, such as temperature change and increased salinity.[56–58] Surgery to remove cataracts can be readily performed and fish will regain sufficient sight in healthy eyes for returning to exhibits or community environments.[59]

EUTHANASIA

As with other animals, sometimes it may be necessary to euthanize a geriatric animal. Unfortunately, there are no drugs approved for euthanasia of fish. The American Veterinary Medical Association Panel for Euthanasia 2007 included several alternatives for euthanizing poikilothermic animals including fish.[60] For fish, the anesthetic agent Tricaine methanesulfonate (MS-222) can be used at high doses of 300 ppm dissolved in water, and for larger animals doses of 300 to 400 ppm can be flowed continuously over the gills using a submersible pump or dose syringes going in a cranial to caudal direction. MS-222 is acidic and should be buffered at a 1:1 or 1:2 ratio with sodium bicarbonate to buffer the pH of the euthanasia bath. When opercular movements cease, the animal should remain in the anesthetic bath or with continuous flow for an additional 20 to 30 minutes. The heart rate should be monitored using a Doppler and the animal can be checked for withdraw reactions or painful response. The heart may continue to beat for several hours after death but the rate will be irregular and slow because of the independent pacemaker cells in the fish heart.[61]

One of the most important diagnostic tools for collections or community groups of aquatic animals is necropsy.[62] A great deal of information can be gathered from a properly conducted necropsy of fresh mortalities. This information is invaluable for protecting the remaining animals.

SUMMARY

Because of the lack of peer-reviewed and evidenced-based literature for the geriatric care of fish patients, it is important to make thorough records for fish patients and be able to search these records when needed. This article serves to provide scaffolding for providing veterinary care from fry through adult for aquatic animals, and as more advanced diagnostics and treatment options are modified and adapted for fish, clinicians should build upon and share these limited experiences so veterinarians can advance their knowledge of aquatic poikilotherms and invertebrates. With improved husbandry and nutrition, geriatric veterinary care and euthanasia for aging fish patients will become more commonplace and private practitioners will need to appropriately provide for these animals and their owners.

ACKNOWLEDGMENTS

REFERENCES

1. Woodhead AD. Aging the fishy side: an appreciation of Alex Comfort's studies. Exp Gerontol 1998;33(½):39–51.
2. Griffith OL, Moodie GEE, Civetta A. Genome size and longevity in fish. Exp Gerontol 2003;38:333–7.
3. Reznick D, Ghalambor C, Nunney L. The evolution of senescence in fish. Mech Ageing Dev 2002;123:773–89.
4. Reznick DN. Life history evolution in guppies (*Poecilia reticulate*): guppies as a model for studying the evolutionary biology of aging. Exp Gerontol 1997;32(3):245–58.
5. Reznick DN, Buckwalter G, Groff J, et al. The evolution of senescence in natural populations of guppies (*Poecilia reticulata*): a comparative approach. Exp Gerontol 2001;36:791–812.
6. Calliet GM. Age determination and validation studies of marine fishes do deep dwellers live longer. Exp Gerontol 2001;36:739–64.
7. Kohda M. A damselfish living for more than 15 years: a longevity record for small reef fishes. Ichthyol Res 1996;43(4):459–62.
8. Eckert GJ. Estimates of adult and juvenile mortality for labrid fishes at One tree reef, great Barrier reef. Mar Biol 1987;95:167–71.
9. Altman PL, Dittmer DS, editors. Growth, including reproduction and morphological development. Biological handbooks. Washington, DC: Federation of American Societies for Experimental Biology; 1962.
10. Krumholtz LA. Reproduction in the western mosquito fish, *Gambusia affinis* (Baird and Girard), and its use in mosquito control. Ecol Monogr 1948;18:1–43.
11. Flower MSS. Contributions to our knowledge of the duration of life in vertebrate animals - I. Fishes. Proc Zool Soc Lond 1925;1:247–67.

12. Carlander KD. Handbook of freshwater biology I. In: Life history data on freshwater fishes of the United States and Canada, exclusive of the perciformes, vol. 1. Ames (IA): Iowa State University Press; 1969.

13. Moyle PB. Inland fishes of California. Berkeley (CA): University California Press; 1976.

14. Bobick JE, Peffer M, editors. Science and technology desk reference. Washington, DC: Gale Research Inc; 1993.

15. Flower MSS. Further notes on the duration of life in animals. - I. Fishes: as determined by otolith and scale - readings and direct observations on living animals. Proc Zool Soc Lond 1935;(2):265–304.

16. Hinton. Horned shark, gar, mormyriad, characin, carp, armored catfish, arowana, upside down catfish. Available at: http://www.demogr.mpg.de/?http://www.demogr.mpg.de/longevityrecords/.

17. Herald ES, Rakowicz M. Stable requirements for raising sea horses. Aquarium J 1951;22:234–42.

18. Strawn K. Life history of the pygmy seahorse, *Hippocampus zosterae* (Jordan and Gilbert) at Cedar Key, Florida. Copeia 1958;16–22.

19. Moyer JT. Longevity of the anemone fish *Amphiprion clarkii* at Miyake-jima, Japan with notes on four other species. Copeia 1986;1:135–9.

20. Lewis WM. Fisheries investigations on two artificial lakes in southern Iowa II. Fish populations. Iowa State Coll J Sci 1950;24:287.

21. Lewis WM, Morris DP. Toxicity of nitrite: a review. Trans Am Fish Soc 1986;115: 183–95.

22. Camargo JA, Alonso A, Salamanca A. Nitrate toxicity to aquatic animals: a review with new data for freshwater invertebrates. Chemosphere 2005;58:1255–67.

23. Hamlin HJ. Nitrate toxicity in Siberian sturgeon (*Acipenser baeri*). Aquaculture 2006;253:688–93.

24. Shaw BJ, Handy RD. Dietary copper exposure and recovery in Nile tilapia, *Oreochromis niloticus*. Aquat Toxicol 2006;76:111–21.

25. Carrola J, Fontaínhas-Fernandes A, Rocha M. Liver histopathology in brown trout (*Salmo trutta f. fario*) from the Tinhela river, subjected to mine drainage from the abandoned Jales mine (Portugal). Bull Environ Contam Toxicol 2009;83:35–41.

26. Wolf JC, Wolfe MJ. A brief overview of nonneoplastic hepatic toxicity in fish. Toxicol Pathol 2005;33:75–85.

27. Weber E Scott, Newman M. Hydrogen sulfide as a cause of mortality in baitfish ponds. Arkansas Aquafarming 2000;17(1):3–5.

28. Brown SB, Honeyfield DC, Vandenbyllaardt L. Thiamine analysis in fish tissues. Am Fish Soc Symp 1998;21:73–81.

29. Jaroszewska M, Lee B-J, Dabrowski K, et al. Effects of vitamin B1 (thiamine) deficiency in lake trout (*Salvelinus namaycush*) alevins at hatching stage. Comp Biochem Physiol A Mol Integr Physiol 2009;154:255–62.

30. Koski P, Soivio A, Hartikainen K, et al. M74 syndrome and thiamine in salmon broodfish and offspring. Boreal Env Res 2001;6:79–92.

31. Tillitt DE, Zajicek JL, Brown SB, et al. Thiamine and thiaminase status in forage fish of salmonines from Lake Michigan. J Aquat Anim Health 2005;17:13–25.

32. Crow GL, Luer WH, Harshbarger JC, et al. Relationship of water chemistry to serum thyroid hormones in captive sharks with goiters. Aquat Geochem 1998; 4:469–80.

33. Sonstegard R, Leatherland JF. The epizootiology and pathogenesis of thyroid hyperplasia in coho salmon (*Oncorhynchus kisutch*) in Lake Ontario. Cancer Res 1976;36:4467–75.

34. Crow GL, Luer WH, Harshbarger JC. Histological assessment of goiters in elasmobranch fishes. J Aquat Anim Health 2001;13:1–7.
35. Nigrelli RF, Ruggieri GD. Hyperplasia and neoplasia of the thyroid in marine fishes. Mt Sinai J Med 1973;41:283–93.
36. El-Zayadi Abdel-Rahman. Hepatic steatosis: a benign disease or a silent killer. World J Gastroenterol 2008;14(26):4120–6.
37. Spisni E, Tugnoli M, Ponticelli A, et al. Hepatic steatosis in artificially fed marine teleosts. J Fish Dis 1998;21:177–84.
38. Henderson RJ. Fatty acid metabolism in freshwater fish with particular reference to polyunsaturated fatty acids. Arch Tierernahr 1996;49:5–22.
39. Yılmaz E, Genc E. Effects of alternative dietary lipid sources (Soy-acid oil and Yellow grease) on growth and hepatic lipidosis of common carp (*Cyprinus carpio*) fingerling: a preliminary study. Turk J Fish Aquat Sci 2006;6:37–42.
40. Montero D, Robaina LE, Socorro J, et al. Alteration of liver and muscle fatty acid composition in gilthead sea bream (*Sparus aurata*) juveniles held at high stocking density and fed an essential fatty acid deficient diet. Fish Physiol Biochem 2001; 24:63–72.
41. Gauthier DT, Rhodes MW. Mycobacteriosis in fishes: a review. Vet J 2009;180(1):5–6.
42. Roberts H, Palmiero B, Weber ES. Bacterial and parasitic diseases of fish. Vet Clin North Am Exot Anim Pract 2009;12(3):609–38.
43. Weber ES. Gastroenterology for the piscine patient. Vet Clin North Am Exot Anim Pract 2005;8:247–76.
44. Boos S, Schmidt H, Ritter G, et al. Effectiveness of oral rifampicin against myco-bacteriosis in tropical fish. Berl Munch Tierarztl Wochenschr 1995;108(7):253–5.
45. Conroy G, Conroy DA. Acid-fast bacterial infection and its control in guppies (*Lebistes reticulatus*) reared on an ornamental fish farm in Venezuela. Vet Rec 1999;144:177–8.
46. Decostere A, Hermans K, Haesebrouck F. Piscine mycobacteriosis: a literature review covering the agent and the disease it causes in fish and humans. Vet Microbiol 2004;99(3–4):159–66.
47. Weber ES 3rd, Weisse C, Schwarz T, et al. Anesthesia, diagnostic imaging, and surgery of fish. Compend Contin Educ Vet 2009;31(2):E1–9 [online].
48. Groff JM. Neoplasia in fishes. Vet Clin North Am Exot Anim Pract 2004;7(3): 705–56.
49. Weisse C, Weber ES, Matzkin Z, et al. Surgical removal of a seminoma from a Black Sea Bass (*Centropristis striata*). J Am Vet Med Assoc 2002;220(2):280–3.
50. Harms CA, Bakal RS, Khoo LH, et al. Microsurgical excision of an abdominal mass in a gourami. J Am Vet Med Assoc 1995;207:1215–7.
51. Lewbart GA, Spodnick G, Barlow N, et al. Surgical removal of an undifferentiated abdominal sarcoma from a koi carp (*Cyprinus carpio*). Vet Rec 1998;143:556–8.
52. Probasco D, Noga EJ, Marcellin D, et al. Dermal fibrosarcoma in a goldfish; case report. J Small Exotic Anim Med 1994;2:173–5.
53. Harms CA, Lewbart GA. Surgery in fish. In: Bennett RA, editor. Vet Clin North Am Exotic Anim Pract 2000;3:759–74.
54. Scientific American PBS Broadcast. Available at: http://www.pbs.org/saf/transcripts/transcript805.htm. Accessed August 1, 2009.
55. Ashton N, Brown N, Easty D. Trematode cataract in fresh water fish. J Small Anim Pract 1969;10:471–8.
56. Bjerka E, Bjerka I, Moksness E. An outbreak of cataract with lens rupture and nuclear extrusion in wolf-fish (*Anarhicas* spp). Vet Ophthalmol 1998;1(1):9–15.

57. Bjerka E, Bjørnestad E. Is there a connection between rapid fluctuation in water temperature and cataract development in the Atlantic salmon (*Salmo salar L.*)? Bull Eur Assoc Fish Path 1999;19:166–9.

58. Waagbo R, Hamre K, Bjerkas E, et al. Cataract formation in Atlantic salmon, *Salmo salar L.*, smolt relative to dietary pro- and antioxidants and lipid level. J Fish Dis 2003;26:213–29.

59. Bakal RS, Hickson BH, Gilger BC, et al. Surgical removal of cataracts due to diplostomum species in gulf sturgeon (*Acipenser oxyrinchus desotoi*). J Zoo Wildl Med 2005;36(3):504–8.

60. American Veterinary Medical Association (AVMA). Guide to the 2000 report of the AVMA panel on euthanasia. J Am Vet Med Assoc 2001;281(5):669–96. Available at: http://www.avma.org/issues/animal_welfare/euthanasia.pdf. Accessed August 20, 2007.

61. Sherrill J, Weber ES, Marty GD, et al. Fish cardiovascular physiology and disease. Vet Clin North Am Exot Anim Pract 2009;12(1):11–38.

62. Weber ES 3rd, Govett P. Parasitology and necropsy of fish. Compend Contin Edu Vet 2009;31(2):E1–7 [online].